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SCIENCE

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THE NEXT STEP IN IMPROVEMENT IN WHEAT CROPPING—HOW TO INCREASE WHEAT PRODUCTION IN 1918 AND 1919¹

YOUR secretary has requested me to prepare a paper on soil organisms affecting cereal production. The subjects which should come before you at this time are without question of the greatest importance to this nation and particularly to the cereal-producing states, and, of these, none are of greater import than those which touch upon the causes of seed and crop deterioration in cereals, under the general cropping and marketing processes now in use. In the case of wheat on the general market it may be truthfully described as yearly more closely approaching the "no grade" condition because of mixtures of kinds and qualities through the jumbling methods of the handling processes. In the case of the seed used on the land in such general cropped regions, the start or first crops produced are always at "No. 1 quality." The finish is always reached after a gradual yearly reduction in purity, vitality and weight quality, until crop failure ushers in seed importation, and then, final failure of the cereals as the chief crops. Are these consequences a matter of necessity?

I am well aware that agriculturists, fertilizer experts, agronomists, and perhaps some plant pathologists, do not agree with me in assigning as great importance to the rôle of plant diseases and to soil and seed sanitation in cereal cropping as I do. However, stock raising, gardening and

¹ Read before the third Interstate Cereal Conference.

fruit growing communities have in a large way already adjusted themselves to sanitary methods of agriculture. At the risk of appearing too pointed, I bring to you the thought that it is time that cereal agriculture be adjusted so that the cropping methods known under the heading of tillage, crop rotation and soil fertilization may come into their own and prove their real merits through the agriculturists, agronomists and the cerealists getting together on a program which shall properly take into account the teachings of the soil biologists, plant physiologists and pathologists for the great cereal crops as has been done for flower and vegetable farming, for potatoes, fruit cropping and other types of intensive crop culture. It is notorious that aside from the applications of the principles of seed disinfection for the prevention of smut and a considerable work looking toward the selection of disease-resistant varieties very little in an organized way has been done looking toward putting cereal agriculture on a plane of sanitary cropping comparable to the intensive methods used with the crops mentioned.

I think you will agree that the present wheat bushelage can not on the average year be greatly increased by just sowing more acres on the same old areas in the same old way or even in the same districts unless a great change is introduced. How wonderful has been the influence of plant pathology on the grape industry, on the fruit industry, on the apple crop and for the potato crop. When we want to grow these in the best way do we forget all principles of soil sanitation or of disease introduction and modes of distribution and infection? If the principles of sanitation associated with proper cropping methods in these more confined crops have been of benefit, what may they not do for the cereal crops when properly applied and

adjusted to the cropping conditions of each great cereal district.

Now that the governmental officials have appealed to this country to raise the greatest possible wheat crop, what have we done to get it? We have only advocated the sowing of the greatest number of acres in the quickest possible time. Granted that we were unprepared to do otherwise, shall the process be continued? Every conceivable bushel of every conceivable kind of wheat, mixed, diseased or otherwise, has gone into the soil and into any area available. Nothing more can be done now than to see that the crop is properly harvested so as to save the greatest possible bushelage in the best possible condition to prevent its food value from being injured, and particularly, that it may not be spoiled as seed for the crop of 1918-19. If such better harvesting is to occur, it must take place in a sanitary method. If it is to be done intelligently, there must be a comprehensive plan; and those who handle the crop after it is grown should know that their handling processes are as important as the cropping processes.

Experiments in North Dakota with potatoes, flax, wheat and allied cereals, extending over the period of time from 1890 to 1917, dealing always with the problems of seed disinfection, soil purification and cropping methods for the control of disease, allow me to say with assurance that soil and seed infection has largely accounted for the many anomalous results obtained in various extensive experiments on wheat and cereal cropping, particularly as referring to variety tests, the influence of rotation, methods of plowing, tillage, etc.; for it is now known that through all these experiments in all cereal states there has been acting in greater or less virulence the constant attack of seed- and soil-borne diseases, which have not been properly taken into account. This lack of the proper consideration of sanitary measures as affecting

cropping processes accounts chiefly for the reduction of yields and the deteriorated quality of the grain which comes from year to year from the old, rather constantly and extensively cropped cereal areas. I call your attention to the history of wheat cropping in California and in the semi-dry regions of Washington and Oregon as affected by smut epidemics. Ordinarily, in the wetter regions, seed disinfection for the prevention of stinking smut of wheat is all that is necessary. It is not even necessary to have a reasonable crop rotation, but in semi-dry regions the smut spores do not so readily die out by rapid germination; and the combination harvesting and threshing has proved to be a process which quickly undoes the work of possible control of smut through seed disinfection. That process of cutting and threshing the grain and returning the chaff, straw and dust to the soil, evenly distributed, did more than introduce smut. With it goes the spores of a large number of so-called "imperfect fungi," particularly the *Helminthosporia* and *Fusarial* types. These and others have brought about seed and root blighting, and with the smut, drought and other conditions soon throws the crop below a paying condition.

In the hard spring wheat regions of Minnesota, North Dakota, South Dakota and Montana, one readily sees the detrimental influences of extensive cereal culture as affecting the introduction, even distribution and destruction by the "imperfect fungi" as transmitted by the seed to new areas, by farming implements, wind and wash waters, and as imbedded in the soil in the dead bodies of the previous crop.

It is a peculiarity of all these seed and soil borne fungi that they are destructive regardless of the year and soil conditions, and vary in intensity according to weather and soil conditions. Thus in intensely dry seasons, particularly preceding the harvest

time, old wheat lands often produce almost normal, plump seeds, but when there is sufficient water content in the soil and sufficient rainfall during the heading period to make a normal stand and growth for what should be a large yield, these parasites resident in the seed and in the old stubble lands and often evenly distributed during moist weather from plant to plant, bring about a rag-like condition of the cellular tissues of the straw. They invade it at all parts, and bring about an intense blighting of the flowers and ovules at the time of seed formation so that the heads are never properly filled. Under these conditions seldom any of the grains reach normal form as to color, size and weight.

To call your attention to what I have in mind I can do no better than to quote from some previous publications of mine in this line. From Bulletin 13, North Dakota Experiment Station, 1894, p. 26:

It is apparent that after all is said concerning culture of wheat in the northwest, haphazard, careless methods of saving the grains at harvest time are yet to be placed as the chief cause in the reduction of the milling quality of the wheat as it now appears upon the market.

From "Plans for Procuring Disease Resistant Crops" in Report of The Society for the Promotion of Agricultural Science, 1907:

At present the farmers are confused by conflict of authority as to the proper line of seed improvement. For the most part, they believe that seed for crops must be bred to a high standard upon a high-class soil and that it will degenerate when put into general cropping conditions on their farms. . . . The facts remain that crops suffer under systems of constant cropping, while the idea of home grown seed for local crops is fast gaining recognition as right in principle. . . . It is recognized that crop diseases, as well as chemistry of soil and air, play a great, if not master, rôle. . . . Crop yields more often depend upon features of disease resistance, or upon conditions of environment in which disease producing organisms can not be active, than upon whether the soil is especially balanced chemically. Crops fail as often through

rust, blight, wilt and rot, and insect mites on fertile soils as upon unfertile soils.

From "Interpretations of Results noted in Experiments upon Cereal Cropping Methods after Soil Sterilization," in *Proceedings of American Society of Agronomy*, Vol. 2, 1910:

Soils and seed may be, and usually are, infected by several destructive wheat-destroying, parasitic fungi. Indeed, these are found to be apparently cosmopolitan in distribution with the wheat plant. They are especially transmitted in the seed internally, and it seems quite certain that they are sufficient in their influence to account for most of the causes of rapid first crop deterioration and for the difficulties which farmers have in introducing any sort of culture, which will again raise the standard of crops. Their exclusion, in so far as it is perfectly or imperfectly done, is sufficient to account for the anomalies in soil sterilization experiments.

From "Conservation of the Purity of Soils in Cereal Cropping," October, 1910, before Dry Land Congress, Spokane, in SCIENCE, N. S., Vol. XXXII., No. 825:

I recommend both our trained agriculturists and the farmer to look for help from a careful consideration of soil sanitation. . . . I consider it particularly important that this question should be brought before this congress, for this meeting is located at a point west of the center of the last great virgin soil areas of this country. And because, while I recognize the great good that is done by the advocates of the conservation of the chemical qualities of the soil and still remain a strong advocate of the importance of that feature, I feel that we have followed it so persistently as to lose sight of other features which have vitiated many of the conclusions which have been drawn. . . . My belief is that we must yet be able to produce the bread of the world by the use of extensive machinery and upon extensive plans, such as are yet being carried on in the new lands of the west. I have set forth the reasons why this can not be done unless we recognize this question of soil sanitation, or, if you will, the necessity of conserving the virgin purity of the land. I am, however, confident that with the proper understanding of the methods which are now known for selecting seed, disinfecting seed, rotating crops and perfecting the seed bed there should be no necessity of growing wheat upon the costly lands now under

intensified farming systems, and that there is no immediate necessity of abandoning the cropping to cereals on the large plan which is characteristic of the northwest. I believe firmly, however, if we do not thus recognize this matter of the necessity of soil sanitation and soil disinfection by means of proper cultivation, and well-planned series of crop rotation, that, no matter how fertile the soil of one of your western valleys may be, no distant year will see your crop fall very close to the world average for that particular cereal.

From "Cereal Cropping: Sanitation, A New Basis for Crop Rotation, Manuring, Tillage and Seed Selection," in SCIENCE, N. S., Vol. XXXVIII., No. 973, 1913:

Deteriorated wheat, as seen in depressed yields and low quality, as now quite commonly produced in the great natural wheat-producing regions of this country, is not, primarily, a matter of lost fertility or of modified chemical content of the soil, but is specifically a problem of soil and crop management. Crop rotation, for example, is not, primarily a farm process which is likely to conserve the fertility of the soil, but when properly arranged in a system so that the proper crops follow one another, it is definitely a sanitary measure tending to maximum production. . . . Wheat does not do well in the presence of its own dead bodies, not because of any changes which the wheat plants have made in the content of the soil fertility, nor because of any peculiar poisons (toxins) which the crops may be thought to have introduced, but primarily, because of infectious diseases which are characteristic of the crop. . . . Proper methods of soil tillage and handling of manures and artificial fertilizers are not merely measures for supplying plant food, but also involve vital features of a sanitary nature. . . . That there is a real problem before the agriculturists of the world, especially as affecting the question of maintaining the output of wheat in amount and quality, all must agree. The present approximate annual output of 700,000,000 bushels in its occurrence is somewhat analogous to the varying annual output of gold. It is maintained at these approximate figures, essentially not through increased yields of grain of better quality per acre on old cultivated areas through certain exact methods, but rather through the breaking up or turning over of new areas, in the same wasteful methods. The most alarming feature of the whole condition rests not so much in these facts as in the evident rapid deterioration of the quality of grain which invariably accom-

panies the first few years of cropping upon new land areas.

All these statements have to do with the fact that wheat in particular and most cereal grains are attacked by certain parasitic fungi which have been usually considered saprophytes or semi-parasites. They attack in such manner as to invade all parts of the plant body, break down the tissues, clog up the ducts, and rot off the roots, and they are particularly destructive as the seedling and stooling stages, and finally cause blighting and shrivelling of seed. We have developed a particularly interesting method of attempting to purify such internally infected wheat grains and other cereals by special methods of heavy seed disinfection, aiming at seed-coat disinfection. The seedlings are then grown upon agar just as one grows a pure culture of a fungus or a bacterium. This allows proper study of the root characters and other conditions as affected by the organisms, and makes it possible to separate uninfected seedlings to be grown on purified soil. This work has been associated with special studies upon soil and seedling purification in many ways. The results of tests extending over a number of years show that continuous cropping to wheat and flax brings about a continuous cumulative infection of soil and seed. In flax the wilt fungus, *Fusarium lini*, remains indefinitely in fertile soil and makes it essentially sterile for that crop. So, also, certain fungi of wheat eat away at the roots and attack seedling plants from the stubble or seed and through accumulation in the seed carry always an accumulating infection to new or cleaned lands, undoing the proper effects of tillage and crop rotation.

A few of the genera particularly concerned in the destructive work upon wheats are *Alternaria*, *Colletotrichum*, *Helminthosporium* and *Fusarium*. Each of these is peculiarly destructive in its own way, and

in certain years one or other may excel in the destruction of the crop.

To these attacks the wheat plant reacts as best it can by the growing and sending down of new roots, adventitious or brace roots, as fast as the old ones die. Its fibrous rooting capacity stands it well in hand, with the result that, unlike flax, it usually holds on to the ground and does not give an absolute failure, though a very irregular crop is characteristic. The disease generally known as scab falls under the group known as *Fusarial* infections. These no doubt spread from head to head to a certain extent, but by far the largest amount of damage is done by direct attack upon the roots just as in flax-wilt and other *Fusarial* wilts. I need not go further into this phase of the subject.

If the diagnosis is correct, we shall never get the full benefits from the campaign for a better agriculture until steps are taken to rather suddenly and generally bring about an actual compliance in better sanitary methods of harvesting the crop and handling the soil and seed.

Mr. Rockwell Sayre, of Chicago, has not been wholly wrong in his campaign for compulsory crop rotation laws. Our people do not like to be compelled to do anything. Perhaps the better method is to educate, but general education comes too slowly to be effective in any sanitary measure. On small areas such as are occupied in potato cropping and in intensive farming propositions the educational process can be brought about and rather effectively carried into operation, but with the great cereal crops where practically three fifths or more of the entire area of a state is put under wheat and allied cereal culture, these diseases, under present methods, run riot.

What to do: It is with a good deal of temerity that I offer the following suggestions. I recommend through this congress

to the United States Department of Agriculture that it, in association with proper state authorities, immediately put on an extended wheat crop survey, (1) to insure a proper harvesting and selecting of the fields from which seed is to be saved for the crop of 1918, so that selection may be made on the basis of freedom from disease and purity as to variety; and (2) to save the seed so it shall be as free as possible from water effects following the period of maturity; for it is through moisture that the invasion of the seed coats becomes most active. This invasion prevents ordinary seed disinfection from being effective.

With this seed survey a soil survey should go hand in hand as follows: (1) Map and locate the virgin lands of the wheat states; (2) map those lands which have had crops on them for the last five to seven years which are of such nature as not to bear the chief diseases of the wheat crop, and (3) set aside these virgin or clean lands and prepare them for the wheat crop of 1918 and 1919.

As a corollary to the seed and soil surveys, the United States Department of Agriculture should commandeer and contract for sufficient of the wheat coming from the virgin lands or from the field crop inspected areas of the older regions which are found to be free from disease, to redistribute to the lands which by the survey have been found to be essentially free from the chief diseases of wheat. Finally, there should be put on a campaign of education which shall reach every grower of wheat in the United States.

If this national survey of soil and of seed production is to be done so as to be effective on the crop of 1918, the work should start before the harvest of 1917, and be so continuously followed up that the plowing may be done for next year and the ground prepared for early seeding. Somewhat over one half of all the land of North Dakota

has still been untouched by the plow, or at least has not been subject to wheat culture. A similar condition exists in most of the spring wheat-producing states. A proper seed bed for the production of wheat can be made upon this new land if it is broken early in the present summer; and, if it is plowed during any portion of this summer, it can be packed and worked down in fine shape for some crop which is suitable to precede wheat, so that in 1919 the wheat can go into this land without further plowing in the finest possible condition.

To summarize: How shall we improve the bushelage and quality of wheat produced in 1918 and 1919? (1) Put on a field crop survey which will locate seed of highest weight and color quality free from disease infection and weather effects; (2) locate the soils upon which such seed should be seeded; (3) take the proper steps to procure that seed and see that it is sowed. Should the government find it necessary to force a proper consideration of the lands upon which wheat is to be sowed and the use of the proper quality of seed, properly disinfected, it would, in my belief, eventually receive the entire sanction of the American farming and business public and we would learn within two or three years the enormous value which would accrue from proper soil and seed sanitation in the cropping cereals.

H. L. BOLLEY

NORTH DAKOTA AGRICULTURAL COLLEGE,
May 30, 1917

SCIENTIFIC EVENTS
AGRICULTURAL EDUCATION AND RESEARCH
IN CHINA¹

CONSIDERABLE attention is now being devoted in China to agricultural education and experimentation in various classes of institutions. An experiment station was located at Peking in 1907 under the control of the board of agriculture, industry and commerce. An experimental tract of nearly 300 acres is avail-

¹ From the *Experiment Station Record*.